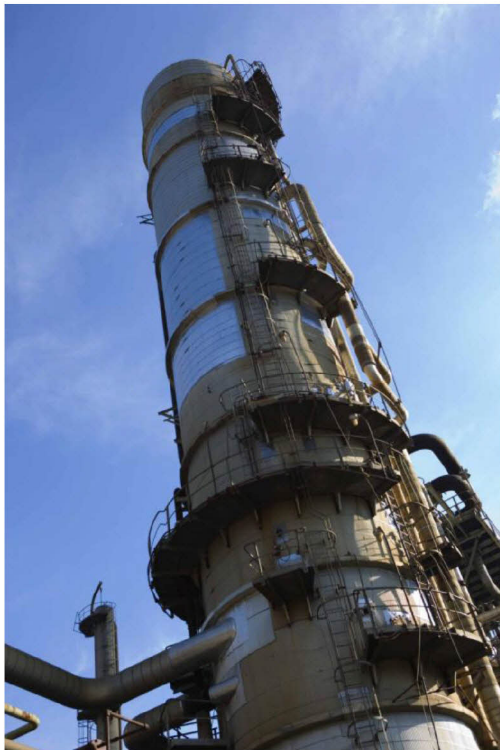


Graphitization



Senior Analyst and Inspector Training Crude Units



Characteristics

- Graphitization can lead to embrittlement and eventual catastrophic failures in equipment and piping
- Occurs in carbon and C-½ Mo steels
- Chromium-containing low alloy steels are immune
- Occurs after long-term exposure above approximately 775°F (410°C) for carbon steel and 850°F (450°C) for C-½ Mo

Graphitization (Cont'd)



- Graphite particles aligned in “chains” are more likely to lead to failure than randomly distributed graphite particles
- Aligned graphite nodules create a plane of weakness susceptible to sudden, low ductility failure
- Graphitization typically occurs in weld HAZs, but base metal graphitization has also been reported
- In crude units the biggest concern is weld areas at the vacuum column inlet

Preventing and Finding Graphitization



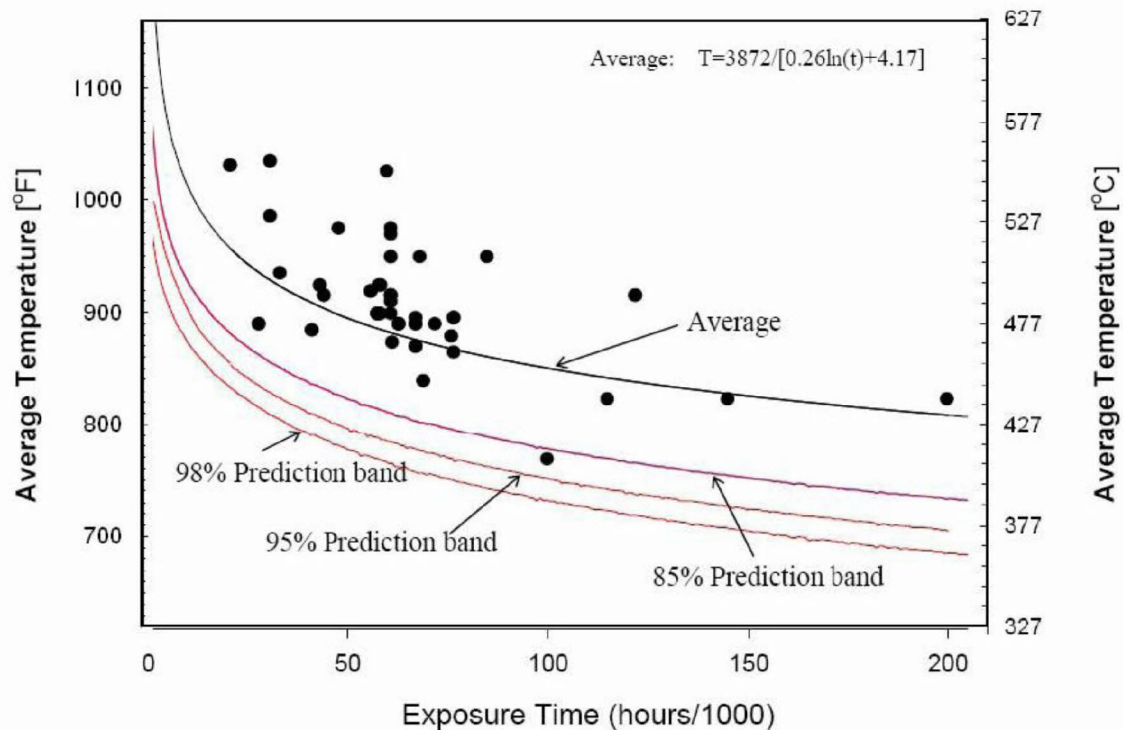
Prevention

- Limit temperature
- Use chromium containing steels

Inspection

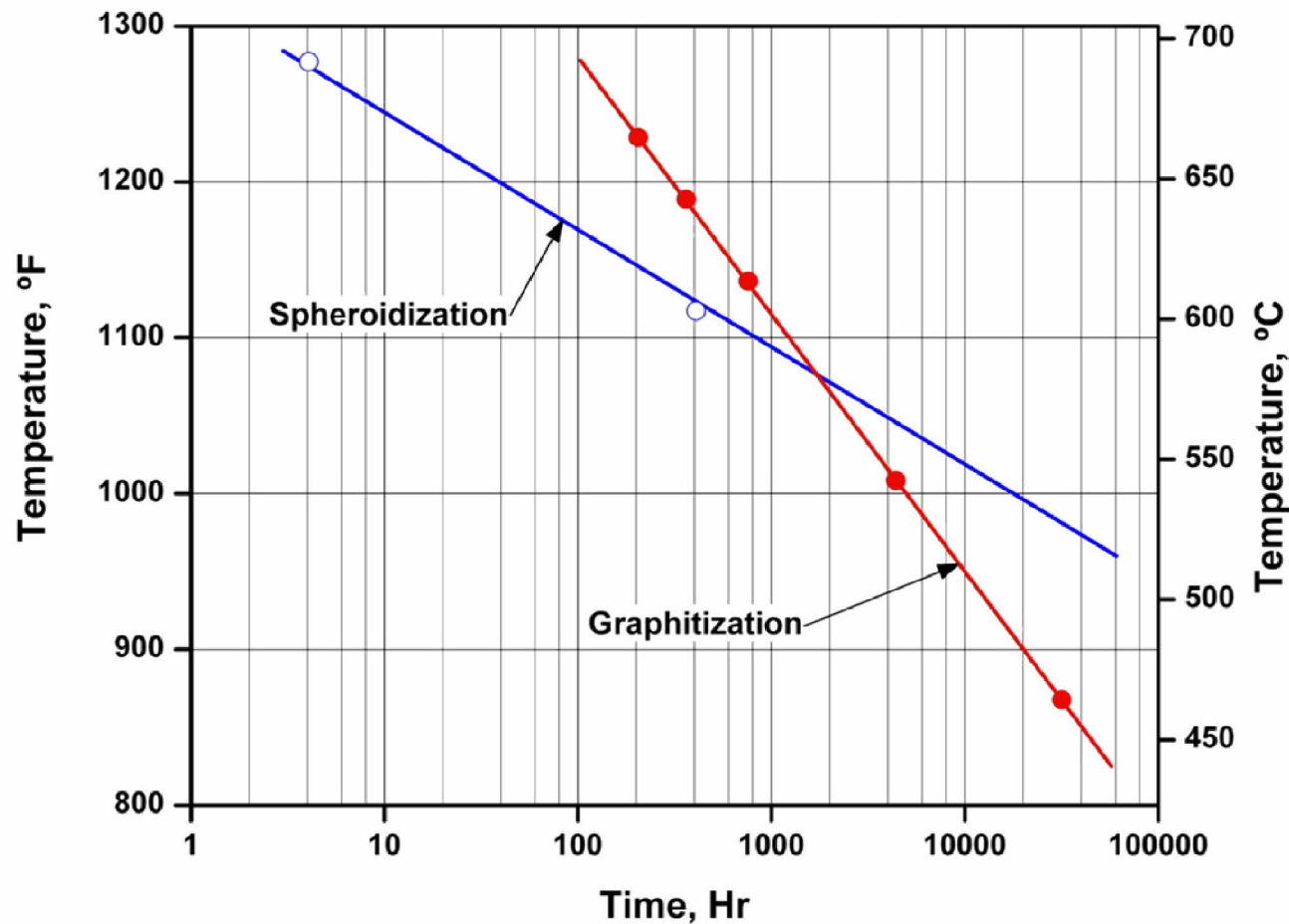
- RT
- Shear wave UT
- Field metallography
- Destructive sampling

Predicting Graphitization

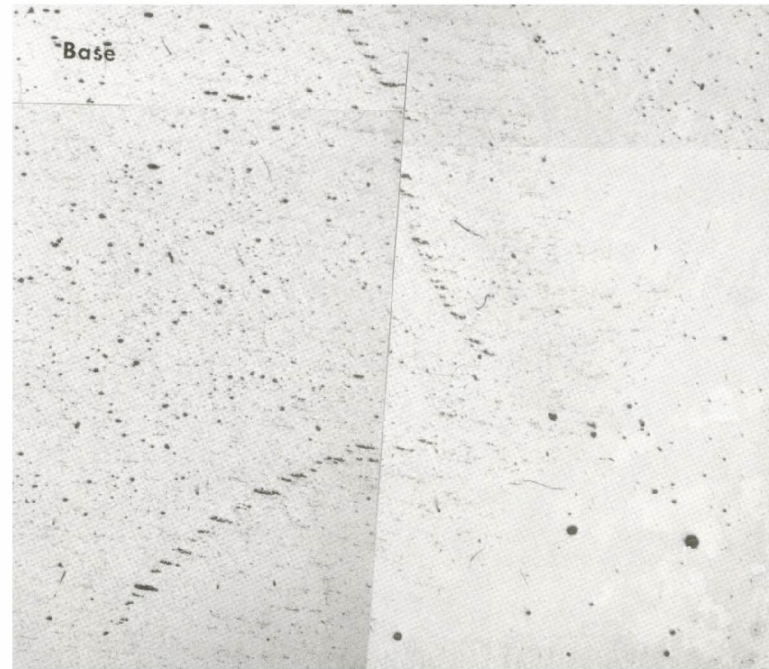
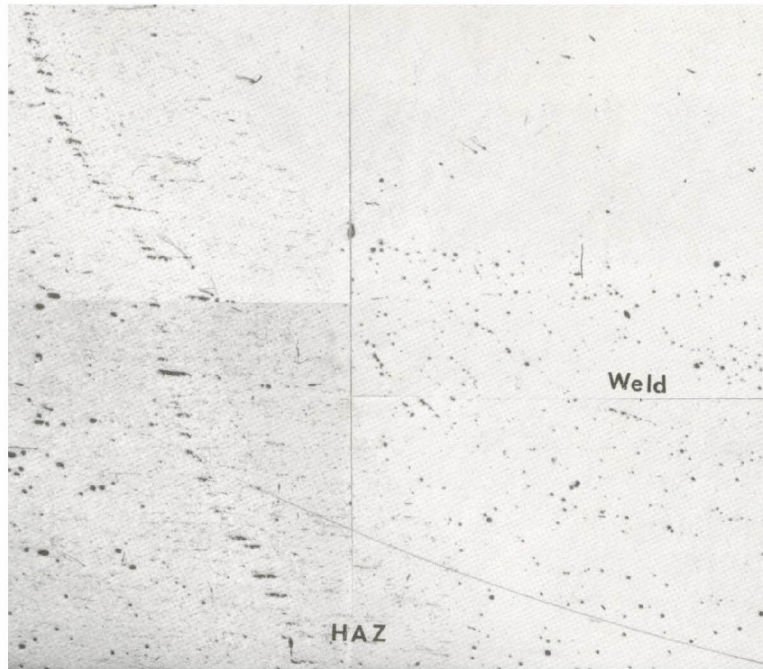


Equipment operating at time and temperature conditions below the 95% prediction band is safe from failure due to graphitization provided stresses are within Code allowable stresses

Time and Temperatures Required for Graphitization

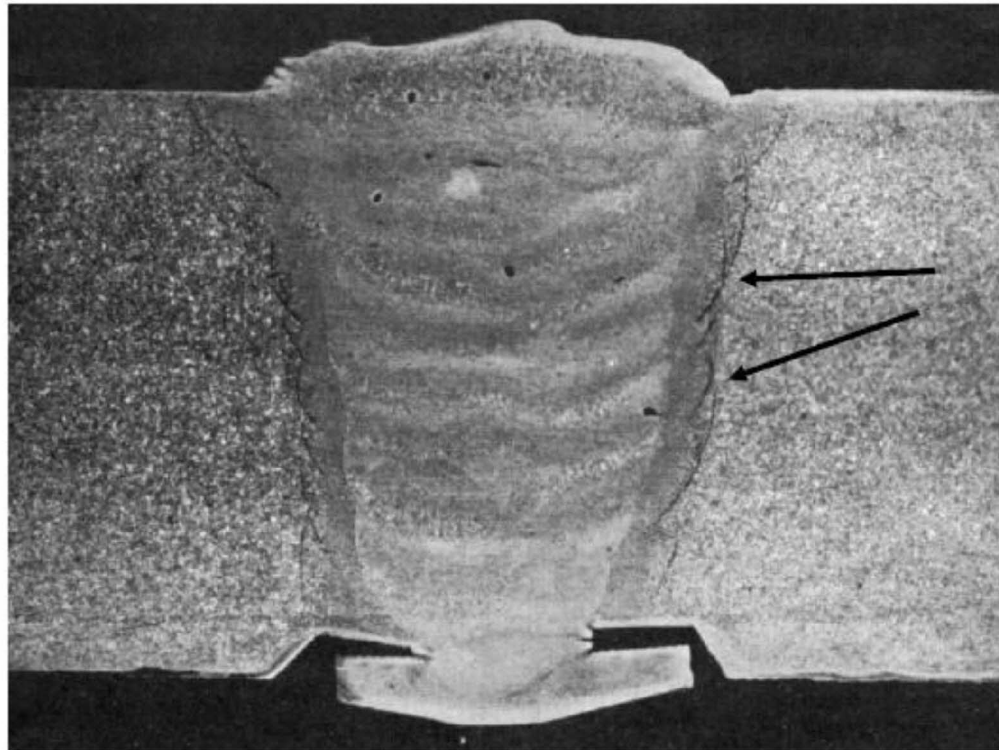


Preferential Graphitization in Weld HAZ of Port Arthur Spent Cat Line



- A201 carbon steel operated for ~263,000 hours at 900-950°F (482-510°C)

Severe Chain or “Eyebrow” Graphitization Adjacent to a Weld



Taken from R. W. Emerson, “Carbide Instability
of Carbon-Molybdenum Steel Piping”

Typical Areas in Crude Units Susceptible to Graphitization



- CS and C-½ Mo after long-term exposure to $T > 775^{\circ}\text{F}$ (410°C) for CS and $T > 850^{\circ}\text{F}$ (450°C) for C-½ Mo
- Potential problem in welded areas of vacuum column inlet

